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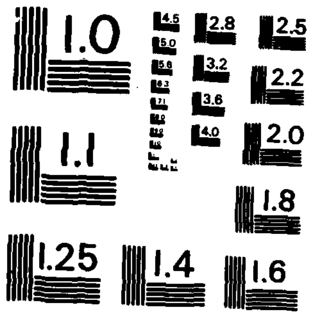

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POSSIBLE BIOLOGICAL IMPACTS OF WAVE WASH AND RESUSPENSION OF SEDIMENTS CAUSED BY BOAT TRAFFIC IN THE ILLINOIS RIVER

by

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The purpose of this report is to evaluate the impact of increased frequency of wave wash and resuspension of sediments, resulting from increased boat traffic, on the biota in the channel and lateral areas of the Illinois River.

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INTRODUCTION

The physical effects, such as waves and turbulence, associated with the passage of a boat in a river channel have been described by Karaki and Van Hoften (1974). They point out that these physical effects are more pronounced in a narrow, shallow river channel such as the Illinois Waterway, than in the relatively wider and deeper Mississippi River. They also note that the bed material in the Illinois below Hennepin (river mile 207) is composed predominantly of silts and clays, which are more easily resuspended by boat traffic and which also take longer to settle, than the sands which largely comprise the bed of the Mississippi. The Illinois thus seems to be especially vulnerable to the physical effects of increased boat traffic. In addition, the areas that are most productive of fish and wildlife in the Illinois Valley, the side channels, backwaters, and bottomland lakes, which flank the main channel, are especially vulnerable to siltation, because the current is reduced in these areas and suspended material tends to settle out.

The purpose of this report is to evaluate the impact of increased frequency of wave wash and resuspension of sediments, resulting from increased boat traffic, on the biota in the channel and lateral areas of the Illinois River.

WAVE WASH

Different wave effects produced by different craft

The types of power boats using the Illinois River can be divided into three classes, based on their wave effects. (1) Small recreational craft, such as flat-bottom john boats and boats used for water skiing, which plane over the water, produce waves a foot or less in height, and cause the least amount of shoreline wave wash. (2) Large recreational craft, such as cabin cruisers and the type of sport fishing boats used on the Great Lakes and the Gulf of Mexico, which push their hulls through the water instead of planing on top of the water, produce short, steep waves of short duration along the shore. These waves can be several feet in height, and are a hazard to small craft. The waves also contribute to shoreline erosion, and noticeably increase shoreline turbidity. (3) Towboats produce three successive effects as they pass a point on shore. First there is a slight rise in the water as the bow wave passes. Then the water is drawn away from the shore. The vertical fall can be substantial, perhaps on the order of 1½ feet. If the shore has a shallow slope, a considerable portion of the bottom may be exposed. Finally, as the stern of the towboat passes, the water rushes back in a series of waves. The water level along the shore may continue to oscillate for many minutes after the towboat has passed. All of these effects are most pronounced

in narrow parts of the river channel, with gently sloping shore-lines. Rapidly-moving pleasure craft produce steep waves of short duration, but not the pronounced drawdown characteristic of the slower-moving towboats.

Biological impacts in the main channel

The drawdown described above can expose bottom-dwelling organisms such as insects, snails and clams. Certain species of mussels are found only in large rivers where there is current, i.e. in, and along the main channel. A survey of the mussels of the Illinois River, conducted by the Illinois Natural History Survey in 1966, showed that there are beds of mussels in the main channel of the river in the Peoria, LaGrange, and Alton navigation pools. Following a protracted period of unusually high water levels in 1972 and 1973, a Illinois Natural History Survey crew examined a bed in the fall of 1974 at river mile 106.6, where mussels were being regularly exposed as towboats passed, and where some mussels had recently died.

Clams will close their shells and snails will withdraw into their shells when exposed this way, thus disrupting their normal activities such as feeding and respiration. If the animals do not open regularly to feed and respire, they will eventually die. Growth and reproduction are probably slowed by levels of disturbance that do not result in death. Some species

of mollusks respond to gradually falling water levels by burrowing into the mud or retreating to deeper water. Based on our observations at mile 106.6, it seems that some mussels do not exhibit this adaptive response to repeated short-term exposures.

Fish would probably not be as greatly affected by wave wash in the main channel as the mollusks. Minnows and some young fish do congregate and move along the shoreline. Dr. R. Weldon Larimore, of the Natural History Survey, has demonstrated that excessive turbidity and turbulence, such as produced by late spring floods in streams, cause juvenile smallmouth to lose their orientation.

Wave action from boat traffic can increase bank erosion. Some of the levees that are used to control water levels in private duck clubs, federal refuges, and state conservation areas along the Illinois River are exposed to the river channel and appear to be suffering erosion from boat traffic. For example, at the Chautauqua National Wildlife Refuge at mile 124.5 the levee on the channel side is eroding although it is protected from wind action and appears to be protected from current, since it is on the inside of a bend. A line of trees that bordered the levee road on the channel side has toppled in where the levee is exposed to the channel, but not where the levee is protected by islands. With the levee broken,

it is impossible to pump out the lake to expose mud flats and grow the moist soil plants which ducks use as food. Drying out a lake also serves to stabilize and compact flocculent bottom muds and partially restore the storage capacity and clarity of the lake when it is reflooded. Both waterfowl management programs and lake restoration programs will be increasingly hampered if levee erosion due to boat traffic increases.

Biological impacts in side channels

Recreational craft do not seem to have much of an impact in side channels unless they actually enter the channel. In contrast, a towboat is capable of altering the rate and direction of flow in a side channel, as it passes first one end, then another of the channel. A small boat in a side channel can actually be carried upstream, as a result of passage of a towboat in the main channel. A rise and fall in water level occurs in the side channel, just as in the main channel, when a towboat passes, although the magnitude is reduced.

Side channels and backwaters are more important breeding nursery areas for most species of fish than the main channel, so turbulence and water level changes here can have a greater direct impact on fish. Species such as channel catfish nest in underbank cavities, and bass and sunfish construct nests in shallow water. Bass in pumped-storage reservoirs where

water levels change markedly twice a day compensate for these changes by constructing their nests at the preferred depth in relation to the low water level, but not in relation to the high water level, so their nests are never exposed. It is not known whether water level changes and turbulence which occur at irregular intervals will elicit the same adaptive response. It is likely that turbulence and flow reversals do disorient juvenile fish and disrupt the parental activities of fish, such as black bullheads, which "herd" and protect their young.

RESUSPENSION OF SEDIMENTS

Karaki and Van Hoften (1974) demonstrate, by means of infrared photographs, that towboats resuspend sediment in the main channel. An observable turbidity trail extends for several miles behind a towboat. In addition, some turbidity measurements made by the Illinois Natural History Survey show the effects of towboats as they pass one point in the river. Figure 1 shows that the turbidity in mid-channel at mile 25.9 was increased by approximately 100 Jackson turbidimeter units (JTU) as towboats passed on three occasions. It took approximately 2½ hours for the turbidity to return to background levels following passage of towboats.

A Natural History Survey crew happened to take a few dissolved oxygen readings in mid-channel on November 6 and 7, 1963,

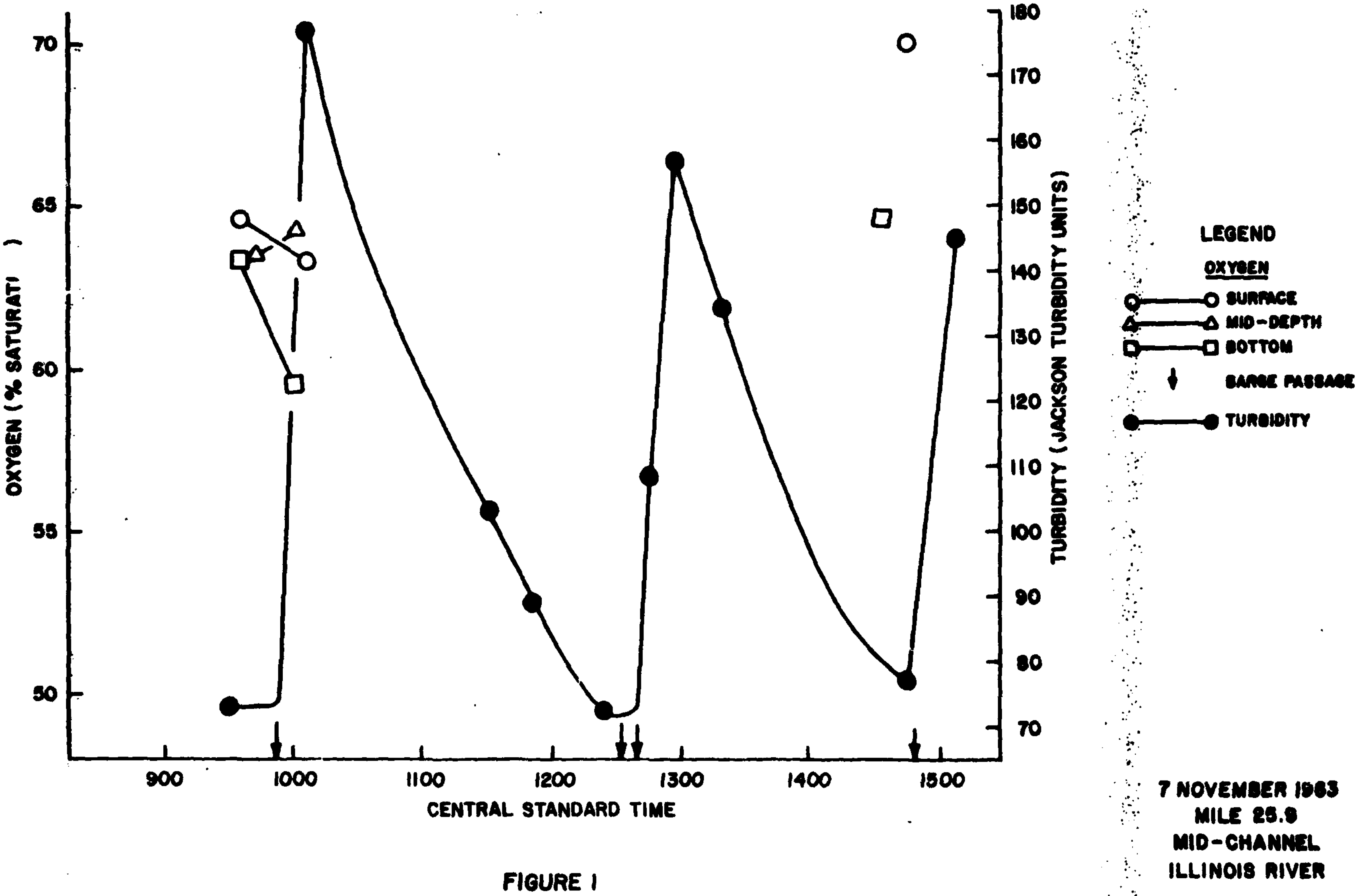
OXYGEN (% SATURATI)
70
65
60
55
50
900
1000
1100
1200
1300
1400
1500
CENTRAL STANDARD TIME
TURBIDITY (JACKSON TURBIDITY UNITS)
180
170
160
150
140
130
120
110
100
90
80
70
LEGEND
OXYGEN
SURFACE
MID-DEPTH
BOTTOM
BARGE PASSAGE
TURBIDITY
7 NOVEMBER 1963
MILE 25.9
MID-CHANNEL
ILLINOIS RIVER

FIGURE I

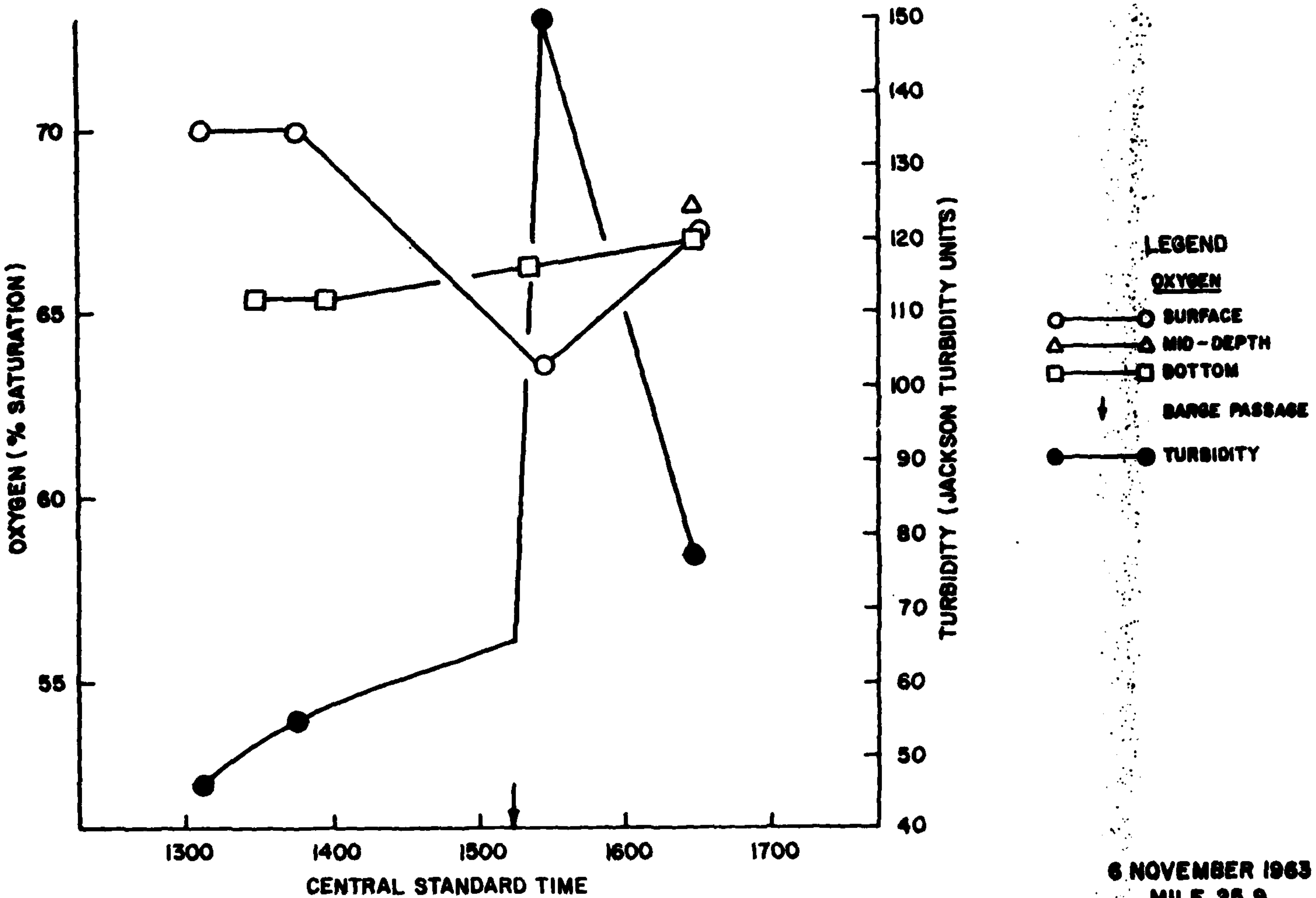

FIGURE 2

6 NOVEMBER 1963
MILE 25.9
MID-CHANNEL
ILLINOIS RIVER

before, during, and after towboats had passed (Figures 1 and 2). One might expect turbulence from barge traffic to aerate the water. Surprisingly, the oxygen levels at the bottom and the surface declined following passage of a towboat on November 7, and declined at the surface, then recovered, on November 6 after a towboat passed. It is not known why oxygen levels at the bottom increased slightly on November 6, and oxygen levels at mid-depth increased slightly on November 7. The declines are significant, because the oxygen levels at the surface on 6 November and at the bottom on 7 November declined by 0.4 mg/l, and the standard deviation of the method used (azide modification of the Winkler method) is 0.1 mg/l, even in the presence of appreciable interference. It is possible that the towboats resuspend oxygen-demanding sediment, causing a slight depression in oxygen levels. Increased towboat traffic therefore might decrease oxygen levels in the river. The data shown in Figures 1 and 2 are not really adequate to determine whether towboats affect dissolved oxygen levels in the river, and this potential impact of increased boat traffic should be investigated further.

The biological effects of sediment resuspension in the main channel and lateral areas are considered in the next sections.

Biological impacts of resuspended sediment in the main channel

Ellis (1936) carried out a series of experiments in which over 2,000 mussels representing 18 common species were exposed to moderate levels of erosion silt in raceways. The silty water came from an unpolluted portion of the Trinity River in Texas, and consisted primarily of adobe clay with very little organic matter. Ellis found that silt interfered with the feeding of the mussels and caused mortality:

> "These experiments, extending over some fourteen months, showed that most of the common fresh-water mussels were unable to maintain themselves in either sand or gravel bottoms when a layer of silt from one-fourth of an inch to one inch deep was allowed to accumulate on the surface of these otherwise satisfactory bottom habitats, although other individuals of these same species held in the lattice-work crates a few inches or feet above the bottom thrived in this same water. Daily analyses of the water at various levels in these raceways showed that the high mortality of the mussels on the bottom was induced by the silt covering and was not due to low oxygen, pH, carbonates or other water conditions. The Yellow Sand-shell (*Lampsilis anodontoides*), a sand-inhabiting species, was the most readily killed by silt deposits, and the Three-horned Warty-back, *Obliquaria reflexa*, the Maple Leaf, *Quadrula quadrula*, and the Monkey-face, *Quadrula metanevra*, were among the more resistant. However, the mortality rapidly approached 90 percent or more for all species when the silt layer began to permanently cover the sand or gravel. On the other hand, the mortality of the mussels in the crates was very low.
>
> Laboratory experiments with fresh-water mussels in water carrying heavy loads of erosion silt (this material being kept in suspension by automatic glass stirring devices) showed that erosion silt interfered with the feeding of fresh-water mussels. The mussels in the muddy water remained closed a large percent of the time, 75 to 95 percent, while

mussels in silt-free water but subject to the same current influences as those in the erosion silt tests were closed less than 50 percent of the time. When mussels opened in water carrying large amounts of erosion silt, an excessive secretion of mucous was produced and this served in part to remove the silt which tended to settle into the mantle cavity. Mussels dying in silt laden water always contained deposits of silt in the mantle cavity and frequently in the gill chambers." (Ellis, 1936: p. 39-40. Material in parentheses inserted by writer.)

It is noteworthy that the yellow sand-shell was most readily killed by silt deposits in Ellis's experiments, and that it has apparently disappeared from the Illinois River, probably due to increased silt loads (Starrett, 1971: p. 334). The monkey-face was always uncommon in the lower Illinois River, because it prefers gravel bottoms in deep water with a current, and the lower Illinois has predominantly mud bottoms. It was probably eliminated from the upper river when dams slowed the current and dissolved oxygen levels became critically low, as a result of sewage pollution (Starrett, 1971: p. 305). The silt-resistant maple-leaf and three-horned warty-back were still found in the Illinois River in 1966 (Starrett, 1971).

Concentrations of fish do appear sporadically in the main navigation channel of the river, but it is unlikely that re-suspended sediment has a direct mechanical effect on them, such as clogging or abrasion of gills. On November 13, 1964, 68 young channel catfish (averaging 3½ inches in total length) were taken in 53 minutes of trawling in the navigation channel

at mile 156. On August 26, 1964, 51 black bullheads (averaging 7 inches in total length) were taken in 49 minutes of trawling at mile 193. Wallen (1951: p. 18) reported that water containing 85,000 Jackson turbidity units (JTU) of montmorillonite clay was fatal to channel catfish and 175,000-270,000 JTU was fatal to black bullheads. Sparks (1969: p. 14) found that sharp crystals of calcium sulfate caused channel catfish to die in four days of exposure when 24,200-30,400 mg/l was kept in suspension. Sparks (1969) measured concentrations of suspended solids by filtration and weighing, while Wallen (1951) used a Jackson turbidimeter, but their results can be roughly compared by assuming that 1 JTU equals 1 mg/l of suspended material. The fact that it took much less suspended calcium sulfate to kill channel catfish than montmorillonite clay indicates that direct effects of particles on fish depend not only on the quantity of particles, but also on properties such as shape, hardness, and size. To harm fish directly, even sharp particles must be in higher particle concentrations than are found in the Illinois River.

Fish are found in rivers with turbidities equal to, or exceeding the turbidity of the Illinois River. Cairns (1968) reported that healthy individuals of 28 species, including channel catfish, existed in the Kansas River in 1958 although the turbidity was greater than 72,000 JTU. During low flow periods, turbidities in the Alton Pool of the Illinois River, the most turbid of the navigation pools, ranged from 36-320 JTU.

Following passage of a barge the maximum turbidity observed was 320 JTU (Starrett, 1971: p. 273).

Heavy metals associated with bottom sediments do not appear to accumulate in food chains in the Illinois River (Mathis and Cummings, 1973). Pesticides are known to adsorb to silt particles, where they can be ingested by bottom organisms. However, an analysis of 14 mussels representing seven species, taken from the Illinois River in August, 1966, showed that concentrations of organochlorine pesticides were low. In no instance did the total concentration exceed 0.0585 ppm and the average content was 0.0331 ppm (Starrett, 1971: p. 358).

As mentioned above, resuspended sediments may exert an oxygen demand in the Illinois River. Oxygen levels in the Illinois are already low in mid-summer due to nitrification oxidation. Ammonia is introduced to the river in sewage effluent from Chicago and the Pekin-Peoria metropolitan area, and oxygen is withdrawn from the water as ammonia is converted to nitrate. The growth of largemouth bass, a species found in the Illinois River, is retarded when oxygen levels drop below 70% saturation, and mortality of juvenile bass occurs below 35% saturation (Carlson and Siefert, 1974). Oxygen levels below 70% saturation have occurred regularly in July and August throughout most of the length of the river, and oxygen levels below 35% have occurred in many sections of the river. Since oxygen levels

appear to be critical in the river, any further reductions would have a serious impact on aquatic life.

Biological impacts of suspended sedimentation in lateral areas

The contribution that boat traffic makes to sediment loads in backwater areas needs to be assessed. Existing sediment loads are already causing sedimentation and turbidity in lateral areas, and may be reducing dissolved oxygen levels. The biological impacts of each of these effects are discussed below.

Sediment is carried by the river into bottomland lakes and backwaters during periods of high water. Valuable wildlife and fisheries habitat is thus being physically lost. For example, sediment deposits have reduced the storage capacity of Lake Châutauqua, near Havana (river mile 124-130) by 18.3 percent in 23.8 years (Stall and Melsted, 1951: p. 1). Areas in Quiver Lake near Havana where boats could formerly be launched are now only a few inches deep in low water stages, and willows are encroaching on the lake. Lakes such as Quiver and Chautauqua provide habitat for fish and migratory waterfowl. An electrofishing survey of the Illinois River, conducted by the Natural History Survey (Sparks, 1974) revealed that the largest numbers of gamefish are taken in those navigation pools that have the greatest connecting lake acreage, Peoria and La Grange Pools. The importance of these areas for fish and wildlife is officially recognized by federal and state government.

Lake Chautauqua is a national wildlife refuge for migratory waterfowl, and there are satellite federal refuges at Meredosia Lake (mile 71-78) and Weis Lake (mile 192-193). There are numerous state conservation areas scattered along the whole length of the Illinois River.

Sediment not only removes habitat, it alters habitat. Suspended sediment reduces light penetration, which reduces the plant photosynthesis that is the basis of productivity in lakes. Rooted aquatic plants are now practically absent from bottomland lakes that are periodically overflowed by the river. Plants such as coontail and sego pondweed furnish food for ducks and a substrate for the insect larvae that are food for young game fish. Once the rooted aquatic plants begin to disappear, a vicious cycle ensues. The bottom is more easily stirred by waves because there are no roots holding it, and waves are more easily generated by wind, because there are no plant leaves to offer resistance. Waves tear additional plants loose from the bottom and increase the turbidity of the water. Jackson and Starrett (1959: p. 160) found that an increase in wind velocity from light to strong increased the turbidity in Lake Chautauqua from 162 to 700 JTU, and that it took a calm period of 7 to 12 days for much of this sediment to settle. As a consequence, Lake Chautauqua and other bottomland lakes are now extremely turbid most of the time.

The turbidity levels in bottomland lakes and backwaters along the Illinois River are within the range that reduces fish production. Buck (1956) studied fish production in farm ponds, hatchery ponds, and reservoirs in Oklahoma which had a wide range of turbidities. The farm ponds were rotenoned, then restocked with largemouth bass and bluegills or largemouth bass and redear sunfish. A total of twelve farm ponds was divided into three turbidity classes. After two growing seasons, the average total weights of fish were:

clear ponds (less than 25 JTU)	161.5 lb/acre
intermediate ponds (25-100 JTU)	94.0 lb/acre
muddy ponds (> 100 JTU)	29.3 lb/acre

The sunfish reproduced more abundantly and grew faster in clear water. Survival of bass was greater in intermediate ponds than in clear ponds, perhaps due to competition with abundant sunfish populations in the clear ponds. However, the surviving bass grew faster in clear ponds:

	average weight gain	average length increase
clear ponds	14.0x	6.9 inches
intermediate ponds	7.1x	5.1 inches
muddy ponds	2.5x	2.4 inches

The results from hatchery ponds, where turbidities were artificially controlled, and from the reservoirs, generally

paralleled the results from the farm ponds, with two exceptions. Channel catfish survived better in turbid ponds, although growth of survivors was better in clear ponds. Both channel catfish and flathead catfish were abundant in a turbid reservoir, although channel catfish again grew faster in clear reservoirs. Channel catfish spawn in dark cavities, such as hollow logs or in holes in banks. In turbid waters, there are probably more suitably dark cavities available per surface acre or length of shoreline than in clear waters, hence, reproduction of channel catfish was probably greater in turbid waters. Flathead catfish grow well in turbid waters and appear to be well adapted to turbid conditions. Buck (1956: p. 257) concludes that in newly formed reservoirs, bass, crappies, and other scaled fish out-produce catfish and then limit them by predation on the young. Turbid waters offer catfish protection from these predators. In addition, sunfish and bass prefer to construct nests on firm substrates, rather than mud. Their eggs and fry are probably more susceptible to smothering by sediment than those of catfish and rough fish. Catfish feed on the types of food organisms which can grow in turbid waters with mud bottoms, such as midges, worms, fingernail clams, and snails. Catfish can use their highly-developed sense of smell to locate food, whereas the game fish rely more heavily on sight. Food habits studies have shown that young game fish feed first on

zooplankton, then on insects, then on larger organisms such as fish and crayfish. These types of food organisms are associated with weed beds and moderately clear water. The bottomland lakes along the Illinois River have been transformed from the latter type of ecosystem to a turbid type of system, by the influx of sediment from the river.

Recently, even the fish and duck food organisms which are adapted to mud bottoms have died out in the channel and lateral areas of the middle section of the Illinois. Fingernail clams in this section died out in 1955, and have not since recolonized the area. Attempts to maintain fingernail clams in Meredosia Lake failed in mid-summer, 1974.* The sediments in lateral areas, such as Meredosia Lake, may be exerting an oxygen demand that reduces dissolved oxygen to critical levels. In addition, toxicants such as hydrogen sulfide can be formed and released from bottom muds under anaerobic conditions.

Ellis (1936: p. 40-41) found that organic matter mixed with erosion silt created an oxygen demand in water and that the oxygen demand was maintained ten to fifteen times as long as the oxygen demand created by the same amount of organic material mixed with sand. Silt particles have the capacity to adsorb and concentrate nutrients from water. Electron photomicrographs (Tahoe Research Group, 1975: p. 67) reveal that silt particles furnish a substrate for bacteria which can utilize

* Illinois Natural History Survey, unpublished data.

the nutrients. Bacterial respiration can thus contribute to oxygen demand.

During the spring and fall waterfowl migrations, excreta from ducks and geese add substantial amounts of nutrients to bottomland lakes and backwaters. The rooted aquatic plants which formerly grew in these areas probably tied up these nutrients, and held the bottom material so that it was not stirred by waves. The nutrients were therefore not available in the water column to cause a chemical or bacterial oxygen demand. In addition, an influx of ground water from sandy bluffs on the east side of the Illinois River, from Kingston Mines (mile 145.3) to Meredosia (mile 71.1), probably helped to maintain clean sandy bottoms and adequate dissolved oxygen levels in the bottomland lakes on the east side of the river. According to an Illinois Water Survey report (1973: p. 19), this influx amounts to 309 cubic feet per second (cfs), or about one-twelfth of the total input to this section of the river, during the lowest flow expected for a seven-day period at a recurrence interval of ten years. Mud now blankets the sand in lakes such as Chautauqua Lake and Quiver Lake, and may reduce the influx of ground water to these areas. On the other hand, the flow might still be sufficient to provide clear water to the lakes if the bottoms could be stabilized against wave action and the influx of sediment from the river reduced or prevented.

At any rate, low dissolved oxygen levels in bottomland lakes on both the east side and west side of the Illinois River (there is little inflow of ground water on the west side) did not result in fish kills or kills of food organisms prior to 1950, when the lakes were generally clear and filled with rooted aquatic plants during summer low flow periods.

SUMMARY

1. Drawdowns of water resulting from passage of towboats can expose substantial portions of the bottom and bottom-dwelling organisms.
2. Wave wash from towboats and large pleasurecraft may increase bank erosion, which adds to the turbidity of the river and which can reduce the low levees used for managing water levels in conservation areas. Levees and pumping operations are essential for keeping turbid river water out of desirable areas, for exposing mud flats in order to grow duck food plants, and for restoring degraded areas by drying and compaction of flocculent bottom muds.
3. Movement of towboats in the main channel can cause changes in the direction and magnitude of current in side channels, and may result in disruption of spawning activities of fish and disorientation of juvenile fish.
4. Towboats resuspend sediment in the main channel. If this

sediment moves into backwaters and bottomland lakes when these areas are connected to the river, then turbidity and sedimentation will increase in these areas. Sediment has direct and indirect effects which have tended to shift the composition of fish populations in bottomland lakes from game fish to catfish and rough fish. Since 1955, even the food organisms for the rough fish and catfish appear to have been affected by low oxygen levels. Illinois River sediment apparently exerts an oxygen demand which lowers dissolved oxygen concentration in the lakes and backwaters, which historically have been the nurseries for the tremendous sport and commercial fisheries of the Illinois River.

LITERATURE CITED

Buck, D. Homer. 1956. Effects of turbidity on fish and fishing. Transactions of the Twenty-First North American Wildlife Conference, p. 249-261.

Cairns, J. Jr. 1968. Suspended solids standards for the protection of aquatic organisms. Proceedings of the 22nd Industrial Waste Conference, Engineering Bulletin Purdue University, Part I 52 (3): 16-27.

Carlson, A.R. and R.E. Siefert. 1974. Effects of reduced oxygen on the embryos and larvae of lake trout (Salvelinus namaycush) and largemouth bass (Micropterus salmoides). Journal of the Fisheries Research Board of Canada 31(8):1393-1396.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17(1):29-42.

Jackson, H.O. and W.C. Starrett. 1959. Turbidity and sedimentation at Lake Chautuaqua, Illinois. Journal of Wildlife Management 23(2):157-168.

Singh, K.P. and J.B. Stall. 1973. The 7-day 10-year low flows of Illinois streams. Illinois State Water Survey Bulletin 57. 24 p.

Sparks, R.E. 1974. An electrofishing survey of the Illinois River. Final report prepared for the U.S. Army Corps of Engineers, Waterways Experiment Station. Vicksburg, Mississippi. 84 p.

Sparks, R.E., J. Cairns, Jr. and F.B. Cross. 1969. Some effects of a neutral mixture of calcium oxide and sulfuric acid on channel catfish, Ictalurus punctatus (Rafinesque). Transactions of the Kansas Academy of Science 72(1):1-15.

Stall, J.B., and S.W. Melsted. 1951. The silting of Lake Chautauqua, Havana, Illinois. Illinois Water Survey Report of Investigations 8. 15 p.

Starrett, W.C. 1971. A survey of the mussels (Unionacea) of the Illinois River: a polluted stream. Illinois Natural History Survey Bulletin 30(5):266-403.

Tahoe Research Group. 1975. Tahoe's troubled waters. Natural History 84(1):60-67.

Wallen, I.E. 1951. The direct effect of turbidity on fishes. Bulletin Oklahoma Agricultural and Mechanical College, Series 2, no. 48. 26 p.

Mathis, B.J. and T.F. Cummings. 1971. Distribution of selected metals in bottom sediments, water, clams, tubificid annelids, and fishes of the middle Illinois River. University of Illinois, Water Resources Center, Research Report No. 41. 45 p.

OTHER REFERENCES

Committee on Water Quality Criteria. 1972. Suspended and settleable solids, p. 126-129. In: Water Quality Criteria 1972. U.S. Government Printing Office, Washington, D.C.

Irwin, W.H. and J.H. Stevenson. 1951. Physiochemical nature of clay turbidity with special reference to clarification and productivity of impounded waters. Bulletin of Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma. Arts and Sciences Studies. Biological Series No. 4. Vol. 48, No. 3. 54 p.

Wang, W. and D.J. Brabec. 1969. Nature of turbidity in the Illinois River. Journal American Water Works Association 61(9):460-464.

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